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WEAPONS SYSTEMS ANALYSIS

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Often, a weapon system may be approved based on a particular required military capability without due consideration given to other missions which it might or might not be able to perform. This report puts forward a methodology for the analysis of weapons systems, and examines various criteria and attributes that relate to system effectiveness. Criteria and attributes included are system performance, operational readiness, life cycle costing, design to cost, reliability, availability maintainability, producibility, operability, capability,

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) adequacy, logistics, etc. A spectrum of simulation techniques and languages applicable to weapons systems analysis in general and air defense weaponry in particular is identified, defined classified and evaluated with respect to practicality, efficiency and credibility. The report also addresses and evaluates various air defense strategies, techniques and tactics.

PREFACE

This technical report is prepared by Dr. Y. S. Sherif and Dr. N. A. Kheir of the School of Science and Engineering, The University of Alabama in Huntsville; the Principal Investigator of this research effort is Dr. N. A. Kheir, Associate Professor of Electrical Engineering. The purpose of this final report is to provide documentation of the technical study performed on Delivery Order 0008 of MICOM Contract No. DAAH-01-81-D-A006.

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U. S. Army Missile Command.

TABLE OF CONTENTS

LIST OF TABLES

Chapter 1

WEAPONS SYSTEMS ANALYSIS

Introduction

Weapons systems may be divided into three categories: Strategic, tactical and surveillance. Strategic weapons systems are weapons of mass destruction; they are used for direct attack on the homeland of the enemy, and may include nuclear weapons, space weapons, chemical and biological weapons, etc. Tactical weapons are those employed in the area of the battle and may include conventional weapons, tactical nuclear delivery systems (low kiloton range yield) and restricted chemical weapons. Surveillance weapons include orbital satellites, offshore monitoring aircraft and patrol ships, radars, etc. Weapons may also be divided in terms of environment into space, air, land and sea weapons systems. Table I* classifies weapons systems under various categories.

Weapons Systems Effectiveness

The ultimate objective of any system is the performance of some intended function. In the case of weapons systems, this function is called the mission. The term often used to describe the overall capability of a system to accomplish its mission is system effectiveness. In a general context, system effectiveness may be defined as the probability that the system can successfully meet an operational demand within a given time when operated under specified conditions. For a one-shot device such as a missile, system effectiveness may be defined as the probability that the system (missile) will operate successfully (kill the target) when called upon to do so under specified conditions. Effectiveness of weapons systems is often evaluated by several criteria. The following outline is intended to show some of the criteria that must be considered.

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*Tables 1, 2 and 3 appear at the end of Chapter 1.

System Performance

1. Design adequacy (design for change, serviceability, growth)
2. Accuracy
3. Range
4. Adaptability
5. Producibility
6. Operability
7. Invulnerability to countermeasures
8. Accessibility
9. Criticality
10. Longevity
11. Deliverability
12. Quality
13. Safety
14. Human factors
15. Standardization
16. Capability
17. Restrictions on performance (volume, weight, weightlessness, vacuum, lack of atmosphere, etc.)

Operational Readiness

1. Reliability
   (a) System Characteristics
      1. Simple (one shot)
      2. Complex (multiple shots)
      3. Active (radar-missile units)
      4. Passive (stand-by units)
      5. Deterministic
      6. Stochastic
   (b) System Failure
      1. Fail-free
      2. Reconfiguration (redundancy, diversity)
      3. Burn-in
      4. Gradual

5. Instantaneous (catastrophic)
6. Faults-interaction
7. Intermittent
8. Out-of-Tolerance
9. Maladjustment

2. Maintainability
   (a) Inspection and Maintenance Schedules
      1. Periodic
      2. Sequential
      3. Opportunistic
      4. Surveillance
      5. Preventive
      6. Corrective
      7. Emergency
      8. Adaptive
      9. Perfective
   (b) Human System Interface
      1. Serviceability
      2. Training (maintain/replace)
      3. Time to restore system
      4. On line/off line service
      5. Logistic support accessibility
      6. Temporal changes/environment
3. Availability
   (a) General
   (b) Inherent

<u>Life Cycle Cost (LCC), Cost Effectiveness</u>

1. Research and development (Hardware design)
2. Design to cost/affordability
3. Verification
4. Testing
5. Evaluation
6. Validation
7. Modifications
8. Operation
9. Maintenance
10. Reliability Growth
11. Salvage

Table 2 classifies weapons systems analysis methodologies under various categories and Table 3 gives various system effectiveness models applicable to weapons systems analysis.

The optimization of system effectiveness is obtained by balancing of the various conflicting criteria suggested in the list above. These criteria and their attributes are so interrelated that they must be viewed together and discussed within the framework of the overall system to which they contribute. MIL-STD-721B definitions quoted below are used by the Army, Air Force and U. S. Navy.

A. System Performance

System performance deals with the design and lifetime operation of a system so that it can fulfill its mission. To accomplish this objective, various requirements must be met. These are the accuracy of the weapon system (kill probability), range, adaptability to new situations, environments, and recurring hardware changes, operability, accessibility for operation and service, criticality, invulnerability to countermeasures, deliverability, longevity, quality, standardization and safety. Other attributes include the following:

Design Adequacy

System design adequacy is the probability that a system will successfully accomplish its mission, given that the system is operating within design specifications throughout the mission. This probability is a function of such variables as the nature of the mission, the design restrictions, system inputs, man-system interface and system accuracy under the conditions of operation. System design may also include alternative modes of operation, provisions for future change, ease of service and reliability growth [251].

Producibility

Producibility involves all the engineering tasks undertaken to insure a timely and economic transition from system development phase to system production phase. The producibility efforts accomplished during advanced development will be primarily associated with the confirmation of producibility of critical components. Producibility is generally applicable to end item efforts for both major and nonmajor weapon systems.

Producibility plans are developed to assure that specific requirements are justified on the basis of the most economical production rate and manufacturing processes [251, 310].

Capability

Capability is defined as the probability that the system's designed performance level will allow it to meet mission demands successfully provided that the system is available and dependable. Capability accounts for the adequacy of system components to carry out the mission when operating in accordance with the system-design specifications as affected by the environment.

B. Operational Readiness

The operational readiness of a system or equipment is the probability that at any point in time it is either operating satisfactorily or is ready to be placed in operation on demand when used under stated conditions, including stated allowable warning time. Thus total calendar time is the basis for computation of operational readiness. To enhance the concept of operational readiness the following may be considered:

1. Engineering rather than economic consideration should control the decision making process.
2. Maintenance/Replacement materials should be selected for durability.
3. Critical redundant/stand-by subsystems should always be under continuous surveillance.
4. Minimize the number of units that may cause complete failure
5. Availability of logistics support.

Reliability

Reliability relates to the frequency with which failures occur. The most commonly accepted definition of reliability is: The probability that a system will perform satisfactorily for a given mission under specified conditions for at least a given period of time. Mission reliability is the probability that a system will operate in the mode for which it was designed for the duration of a mission, given that it was operating in this mode at the beginning of the mission. Consequently mission reliability defines the probability of nonfailure of the system for the period of time required to complete a mission. The probability is a point on the reliability function corresponding to a time equal to the mission length.

Dependability

Dependability is defined as the probability that an item will enter any one of its required operational modes during a specified mission and perform all the required functions associated with those modes. Dependability may be reassured by the following criteria: (1) point availability or the probability that the system will be operable at a specified instant of time; (2) interval availability or the expected fraction of a given interval of time the system will be operable; and (3) reliability or the probability that the system will not fail during a given interval of time.

Maintainability

Maintainability is defined as the probability that a failed system is restored to operable condition in a specified down time. Maintainability may also be considered as a characteristic of design and installation which is expressed as the probability that an item will conform to specified conditions within a given period of time when corrective or preventive action is performed in accordance with prescribed procedures and resources. The maintainability parameters of a system are those factors (man-system interface, environment, hardware, software, etc.) which establish limits to the performance of corrective or preventive actions. Maintainability and repairability may be analogous. The difference is that maintainability is based on total down time which includes active repair time, logistic time and administrative time, while repairability is restricted solely to active repair time. The maintainability function is the cummulative probability that the failed system is restored to operable condition in not more than a specified down time, expressed as a function of this down time, and the density function is called the maintenance time density function [251].

Inspection and Maintenance Schedules

Inspection and maintenance schedules involve planned and unplanned actions carried out to retain a system in or restore it to an acceptable condition. Optimal maintenance schedules aim to minimize downtime, while providing for the most effective use of systems in order to secure the desired results at the lowest possible costs. The problems encountered in inspection and maintenance scheduling are:

(1) Identification of systems type: active, passive, simple, complex, etc.

(2) Identification of systems failure: instantaneous, burn-in gradual, deterministic, stochastic, under risk, under certainty, undershock, etc.

(3) Identification of system's failure model: increasing failure rate (IFR), decreasing failure (DFR), constant failure rate (CFR), coherent, etc.

(4) Identification of costs of inspection, maintenance, failure detection delay, downtime, etc.

(5) Identification of the quality of inspections: perfect, degrading, etc.

(6) Identification of maintenance policy: as good as new, as bad as old, etc.

(7) Availability of failure data: validation, estimation, etc.

The ultimate goal of maintenance is maximum efficiency at minimum cost, and this may be achieved by having maintenance policies that include the following:

(1) Preventive maintenance

(2) Corrective maintenance

(3) Emergency maintenance

(4) Adaptive maintenance

(5) Perfective maintenance

Preventive maintenance is the planned maintenance of a system resulting from periodic or sequential inspections that disclose faulty conditions. Its purpose is to minimize breakdowns and excessive depreciation resulting from neglect. Corrective maintenance deals with system performance when it gives wrong results. Emergency maintenance deals with non-planned service measures caused by failure indicated by a failure signal device. Adaptive maintenance is concerned with system configurations due to changes in environment; and perfective maintenance is concerned with increasing system availability and implementation of major changes that eliminate inefficiency. Other factors that may effect maintenance policies are: (1) collection and analysis of failure and maintenance data statistics; (b) designing for change, such as modular design, etc., and (c) planning long-range maintenance budget during system development.

Human-System Interface

Almost all operational and stand-by systems need human interface, yet this interrelation is generally overlooked in systems reliability analysis. The assessment of human influence on system performance and the effects of system parameters on human operation would provide an important and critical component in the design and operation of reliable complex systems. Some of the physiological and psychological effects that influence human-system reliability are:

(1) Temporal changes in human performance: perception, recognition response, decision making efficiency, motivation, etc.

(2) Training programs: improvement rates, overconfidence, communications, logistics system organization, etc.

(3) Work environment: work space, layout, noise, comfort, etc.

(4) Optimal environment: procedures safety, monotony, boredom, fatigue, stresses, operation time, duration, number of replacements, etc.

The severity of failures in missile system operations due to human-initiated malfunctions had been discussed in [396]. The study shows that inadequate system-engineering in system development programs together with poor training contribute to the increase in human-initiated failures. Even where the reliabilities of the hardware of military systems are high, human errors may contribute to poor system performance. Henceforth, gaining insight in human system interaction will provide means for the enforcement of overall system reliability and operational readiness.

Logistics

Logistics is the science of planning for, providing and applying the resources required to operate and maintain a given system in a specified operational environment throughout its life cycle. Logistics is integrated in terms of the relationship of its elements to each other, and to logistics as a complete entity; furthermore, it is integrated into the overall system development process. The major logistics elements are: (1) maintenance, (2) supply support, (3) support equipment requirements, (4) facilities requirements, (5) transportation and packaging, (6) technical information, (7) personnel and training, and (8) field support.

Serviceability

Serviceability is a system design characteristic which can be used to represent the degree of ease or difficulty with which a system can be repaired. Serviceability may also be considered as a measure of the degree to which servicing of an item will be accomplished within a given time under specified conditions. Servicing here is referred to as the replenishment of consumables required to keep an item operable, but not including planned or corrective maintenance [266]. Serviceability depends on many characteristics such as complexity of design, provisions for on-line testing, environment, trained maintenance personnel, logistics, etc.

Availability

The availability of a system is the probability that it is operating satisfactorily at any point in time when used under stated conditions, where the total time considered includes operating time, active repair time, administrative time and logistic time. The intrinsic availability is the probability that the system is operating satisfactorily at any point in time when used under stated conditions, where the time considered is operating time and active repair time. In specifying the availability of a given system, it is necessary to consider the following three processes: (1) the component failure process, (2) the maintenance process, and (3) the operation process and system configuration. The above mentioned definitions of availability are based upon the following assumptions: (1) failures are independent at the subsystem level, (2) simultaneous failures will be corrected sequentially, and (3) the probability of failure of an element while another element is being repaired is zero.

C. Life Cycle Costing (LCC)

Life cycle costing is the total cost of acquiring a product, establishing the necessary logistics base from which to deploy and use the product, and maintaining it in operable condition over some prescribed period of time. LCC can also be defined as the total cost of a system from inception through its disposal. This includes (1) research and development cost (initial planning, feasibility studies, product research, engineering design, etc.), (2) production and construction cost (manufacturing, production operations, quality control, etc.), (3) integrated logistic support and (4) disposal cost.

During a weapons systems life cycle, the logistic support fundamental characteristics are as follows: (1) the cost of operating and supporting a weapon system throughout its life cycle often far exceeds the cost of designing, developing, and processing the weapon system, (2) the majority of the operating and support costs for a weapon system are fixed by the time the weapon system reaches its development stage in its life cycle, (3) the total logistic support for a weapon system is comprised of a number of interrelated elements, (4) the effectiveness of the logistic support system is maximized through optimization of the system and not through optimization of the individual elements of the support system [441].

Life cycle cost analysis may include the following [449]:

(1) Definition of a system or product in terms of its cost characteristics

(2) Definition of the system or products life cycle and all the activities that generate costs

(3) Development of a life cycle cost breakdown (LCCBS) that structures those activities to specific category of accountability

(4) Development of cost estimating relationships (CER) for each element in the (LCCBS).

(5) Development of an LCC estimating model

(6) Development of CER inputs and estimation of life cycle costs in constant dollars.

(7) Development of cost profiles from LCC estimates.

(8) Development of discounted life cycle costs.

(9) Development of escalated life cycle costs.

(10) Identification of cost drivers.

(11) Determination of cause and effect relationships.

Cost Effectiveness

Cost effectiveness is an evaluation and analysis of alternatives by measuring their capabilities to accomplish a desired requirement or task and the resource implications necessary to achieve these capabilities. Cost effectiveness is the actual quantitative accomplishment of an operational system compared to its total program cost. It may be expressed as a ratio of system effectiveness to program cost. When effectiveness can be converted to system worth, then cost-effectiveness can be expressed as the difference between worth and cost of net gain.

Design to Cost (DTC)

Design to cost concept establishes life cycle cost as a system design parameter along with performance effectiveness; however cost targets (affordability) are initially established at program inception as input criteria, and subsequent activities and design decisions are directed toward compliance with these targets. Here cost is assumed to be an active rather than a resultant factor throughout the design process. The basic steps for DTC goal setting may include the following: (1) estimate the mission worth, (2) explore and estimate costs of alternate or substitute systems, (3) estimate the cost and performance impact of new technology in product design and manufacturing process, (4) evaluate the potential usage for the new system, (5) evaluate the competitive environment, (6) determine life-cycle cost sensitivity to unit production cost, and (7) establish future production cost distribution without exceeding thresholds or set goals. Design to cost (DTC) started as a commercial concept, then it has been adapted to Government procurements. Commercially, the concept is that a unit production price is established that the market place is willing to pay for a given product. That price becomes a design parameter. Limits are set on both minimum acceptable performance and maximum expected volume. Design tradeoffs are made within these limits. The Government's adaptation of this concept defines DTC as: A management concept wherein rigorous cost goals are established during development and the control of these goals is achieved by practical tradeoffs between operational capability, performance, cost and schedule. Cost becomes a design parameter.

Design to cost (DTC) implementation includes: (1) the generation of "design to" goals based on affordability levels, (2) allocation (pass down) of these goals to the designers of various hardware-software elements. This pass down is compatible with reliability, maintainability and support requirements which impact life cycle cost, (3) implementation by the designer through the synthesis of hardware-software concepts within production cost limits, (4) cost tracking through updated cost estimates [449].

Relationships Among Time Elements

Calendar time may be divided into available time and unavailable time. Available time is that time during which the system is available for use by the intended user; unavailable time is that time during which the system is being supplied, repaired restored or kept in condition for its intended use. Available time may be further broken down into usage time (during which the carrier of the system is employed for its intended tactical purpose) and ready time (during which the carrier is available for use but is not in tactical service). Usage time may be further subdivided into operate time and stand-by time. Operate time is that time during which any portion of the system is fully energized. During stand-by time, any portion or all of the system is partially energized, but no portion of the system is fully energized. Insofar as unavailable time is concerned the interval of primary interest is repair time-that time in which maintenance is being done or manpower is otherwise being expended on the system. The other component of unavailable time is waiting time. This term applies primarily to time lost for administrative and logistic reasons such as time until maintenance personnel have an opportunity to start repair work on an item. A period of waiting time can occur during an interval of repair time-for example when parts required for repair are not available [252, 266].

Table 1 Classification of Weapons Systems

Strategic Weapons Systems

- Missiles
  - Intercontinental ballistic
  - Intermediate and short range ballistic
  - Antiballistic
  - Air to surface
  - Submarine launched ballistic
  - Submarine launched cruise
- Chemical and biological systems
- Orbital satellite systems
- Long range radar and surveillance systems

Ground Forces

- Armored vehicles
- Artillery
- Logistics
- Missiles
- Reconaissance and warning systems
- Target acquisition systems

Naval Forces

- Surface warships
  - Heavy: aircraft carriers, destroyers, etc.,
  - Light: hydrofoil, landing ships, hovercraft
- Submarines
  - Conventional
  - Nuclear
- Missiles: antisubmarine, ship to surface, ship to air
- Logistics

Table 1 (Cont'd)

Air Force

- Aircrafts
  - Combat: Bombers, ground attack, interceptors, etc.
  - Transport
  - Helicopters
- Deep penetration systems
- Long range deterrent launcher vehicles
- Missiles
- Logistics

TABLE 2 WEAPONS SYSTEMS ANALYSIS METHODOLOGIES

Analysis Type	References
<u>**Weapons Systems**</u>	
Analytical Analysis	7, 9, 11, 22, 27, 38, 45, 56, 61, 89, 102, 117, 119, 123, 128, 134, 147, 165, 166, 173, 176, 186, 192, 202, 211, 215, 222, 228, 232, 234, 236, 239.
Simulation Analysis	1, 2, 3, 4, 6, 8, 12, 13, 14, 16, 17, 19, 24, 28, 29, 37, 39, 43, 44, 46, 47, 48, 49, 50, 52, 53, 54, 58, 59, 66, 67, 68, 69, 72, 73, 75, 76, 77, 78, 80, 81, 82, 83, 84, 87, 92, 93, 95, 96, 97, 99, 100, 104, 118, 121, 122, 125, 126, 127, 129, 130, 135, 138, 139, 140, 141, 144, 150, 153, 156, 157, 160, 163, 167, 168, 171, 172, 175, 180, 181, 182, 188, 189, 190, 191, 193, 194, 196, 197, 199, 203, 204, 205, 206, 207, 210, 212, 213, 214, 216, 217, 218, 219, 220, 223, 224, 225, 226, 229, 231, 235, 237, 241, 242, 244, 246, 247, 249, 250, 251.
Life Cycle Cost (LCC) Analysis	14, 18, 21, 23, 25, 36, 40, 63, 71, 74, 98, 145, 146, 148, 151, 161, 164, 174, 195, 200, 230, 237, 240, 243.
Reliability Analysis	10, 20, 23, 25, 40, 52, 54, 56, 60, 74, 134, 162.

TABLE 3 SYSTEM EFFECTIVENESS MODELS FOR WEAPONS SYSTEMS ANALYSIS

Model Application	Model Criteria	References
Airborne Avionics Systems	Logistics Reliability	265
Airborne Systems (general)	Reliability System Effectiveness	273
Airborne Weapons Systems	RAM, Capability	313
Aircraft	RAM	308
Air Fighters	RAM	276
Air Force	Cost Effectiveness (LCC)	326
Atlas Centaur	RAM, Design Adequacy	304
Avionics Systems	Availability, Capability	311
Ballistic Missile Defense	Availability, Design, Cost	271
B-52, F-111	RAM	281
B-58, Bombing	Reliability	287
Combat Tank	Reliability	289
F-4	Cost Effectivenoss (LCC)	
Manned Orbital Pesearch	RAM	269
Military Force	Capability, Effectiveness	279
Radar Systems	RAM	252,262
Reentry Vehicle Systems	RAM	286
Unmanned Space Exploration	Mission Reliability	307
U. S. Navy	System Effectiveness	277
Weapons Systems	RAM, Readiness	261, 285, 290, 310
Weapons Systems (Navy)	RAM	302
Weapons Systems (SM-2 Missiles)	Cost Effectiveness (LCC)	18

Chapter 2

SIMULATION TECHNIQUES AND LANGUAGES

APPLICABLE TO WEAPONS SYSTEMS ANALYSIS

Introduction

Since system effectiveness evaluations of weapons systems usually precede development of prototype models of the system, methods of predicting the system's performance capabilities such as target acquisition capabilities, accuracy (hit probability), reliability, lethality, and other performance characteristics are required. Even if prototype models are available to determine these capabilities experimentally, simulation models are needed to predict and estimate performance in geographic areas and hostile environments in which experimentation is not feasible.

Simulation Techniques

Recent years have witnessed the development of a number of simulation techniques and languages that are aimed at simplifying the task of writing programs for a variety of different types of models and systems. Among the simulation techniques that have been developed are the following:

ABSIM	GASP	Monte Carlo	SIMULA
ACSL	GPSS	PLANS	SIMULATE
ADSIM	GSL	PLUG	SLAM
APL/FORTRAN	LASS	Q-GERT	SOL-370
ASPOL		SCERT	TAGWAR
BDSIM	LPL	SDL	TIGER
CADET	MACTRAN	SIMON	Hardware-in-the-Loop
CASE			
CSMP	MACSYMA	SIMPAC	Man-in-the-Loop
CSS II			
DARE-P	MARSYAS	SIMPL/I	Hybrid
DYNAMO	MILITRAN	SIMSCRIPT	
ECSSL	MIMIC	SIMTOS	

These techniques have been developed with the following objectives in mind

1. To produce a generalized structure for designing simulation models.
2. To provide a rapid way of converting a simulation model into a computer program.
3. To provide a rapid way of making changes in the simulation model that can be readily reflected in the machine program.
4. To provide a flexible way of obtaining useful outputs for analysis.

There are two general categories of simulation of interest to the weapons systems analyst. These are tactical simulation and strategic simulation. Tactical simulation is more suited for systems that are relatively well-defined and whose components can be accurately described and mathematically modeled in a satisfactory manner. Strategic simulation involves large-scale models where the size and complexity of the system call for judgement or estimation. Simplicity, relevance and the appropriatness of the aggregation and abstraction are the key elements to successful model-building for simulations [514].

The simulation language best suited for a particular simulation study depends upon the characteristic of the system and upon the programming skill of the individual conducting the study. As a general rule, an increase in the flexibility of a simulation program is obtained at the cost of requiring more understanding of programming techniques. Similarly, reductions in programming time achieved through the use of simulation languages are associated with increases in computer running times and computer costs. The decision whether to use a particular simulation language may be influenced by the following, (1)availability of computer hardware, (2)availability of programmers knowledge in particular computer languages, (3)cost of programming, and (4)cost of computer time.

Tables 4 and 5 organize various application areas of simulation techniques to air defense weaponry and missiles. Table 6 gives a spectrum of simulation techniques and languages that are applicable to weapons systems analysis, together with relevant references for ease of use by the reader. A brief description of various simulation techniques and languages follows:

Characteristics and Applications

ABSIM

ABSIM is a general purpose digital analog system simulator program. It provides simulations of digital, analog and combination digital/analog system models similar to an analog computer simulation but allows a simulation to be more easily and quickly programmed. It has been written in such a way as to be easily run on almost any 16-bit computer with a FORTRAN IV compiler. A wide range of simulation blocks are provided in the program including both predictor-corrector and Runga-Kutta integration. The types of simulation blocks can be expanded in a fairly straight forward manner by adding additional FORTRAN IV statements to the program. To be more efficient, ABSIM could be made to generate FORTRAN or assembly language codes which would then be executed directly instead of the interpretive execution used. Automatic adjustment of step size to achieve a prescribed accuracy could also be implemented.

ACSL (Advanced Continuous Simulation Language)

ACSL is designed for modeling and evaluating the performance of continuous systems described by time dependent, non-linear differential equations. The emphasis is placed on the ability to run and evaluate the model on-line. In ACSL, provision has been made to overcome the problem of high data volume, monitoring information can be directed to the terminal, high volume output to a local line printer. Typical application areas of ACSL are control systems, chemical process representation, missile and aircraft simulation or fluid flow and heat transfer analysis. Program preparation can either be from block diagram interconnection, conventional FORTRAN statements or a mixture of both [1].

ADSIM (Air Defense Simulation)

ADSIM is an all digital modularized program consisting of target threat profiles, sensor models, on-board processor characteristics (including various system controls) and ballistic flight times. ADSIM uses POST2, a post processor to calculate projectile flyout trajectories, miss distance in a vulnerability frame, estimate hit and kill probabilities and summarize all data as a function of time. ADSIM has three definable phases: pre-processing, run and post-processing (POST2). Pre-run activities include processing target position-time history to polar data, placing this data on magnetic tape for rapid access and running the search radar model to determine the mean and standard deviation of detection range which determines the starting point for the run time phase. Target tracking from noisy order returns (generally first order Markov processes), target state estimation, prediction, lead angle generation and gun pointing dynamics are all simulated during the run time phase. Data is also collected on disk files during this phase and organized by Monte Carlo replication number for use by the next phase. During the post-run phase the time histories of gun pointing angles are used as initial conditions for the projectile flyout and gun ballistic dispersion routines. Miss distances, hit and kill probabilities and other data are then calculated [53,207].

BDSIM

BDSIM is a block diagram oriented simulation software system that permits the simulation of a deterministic or stochastic, discrete or continuous time, physical system on the basis of a discription of its functional block diagram given in input. On the basis of such a description, the system is simulated by generating mathematical representations of its various possible behaviors; for deterministic systems, the system behavior is univocal but for stochastic systems, it is in general necessary to generate a statistically significant subset of all the possible system behaviors which can be utilized as a basis for the evaluation of various parameters which synthesize the system behavior in a statistical sense. BDSIM also permits the realization of several simulations of a system in the same computer run, for diverse values of fixed parameters characterizing its various functional subsystems [48].

CSMP

CSMP (Continuous System Modeling Program) is a simulation language written for the simulation of continuous systems. CSMP-1130 version makes use of the block oriented input language. It allows the user an on-line interactive mode of operation while developing and testing continuous systems models. CSMP-1130 has low adaptability for simulation processes of different kinds of disciplines and has only one technique for numerical integration (second-order-Runge-Kutta, modified Euler).

CSMP-III version is equation oriented and allows the simulation of continuous processes directly and simply from either block-diagram representations or a set of ordinary differential equations. It has high flexibility (degree of freedom in describing a process to be simulated), high adaptability, and utilizes seven numerical integration techniques (rectangular, trapezoidal, Simpson's, Runge-Kutta fixed interval, Runge-Kutta variable interval, Milne predictor-corrector and Adams). CSMP-III has the features of nesting, debug-aid, and storage capability [29, 81, 95].

CADET

For many types of nonlinear systems the CADET technique can often be used as a less expensive alternative to the Monte Carlo technique in order to obtain approximate performance projections. The CADET technique employs statistical linearization in conjunction with covariance analysis to yield performance projections in one computer run. CADET has proven itself to be a useful and efficient tool in the preliminary evaluation of missile guidance system performance [73, 249].

DYNAMO

DYNAMO treats certain types of dynamic information feed-back systems that can be described in terms of a set of finite difference equations. DYNAMO makes use of two different types of instructions, equations and directions to obtain step-by-step numerical solutions to the set of difference equations describing the system under study. The basic components of the DYNAMO language are almost identical to those found in FORTRAN because they include the following: variables, constants, subscripts, equations and functions. However, in DYNAMO variables are further subdivided into levels, auxilaries, rates, supplementary variables and initial values. Among the special functions or subroutines which are available with DYNAMO are: exponential, logarithmic, third order delays, step functions, ramp functions, switch functions, etc. [184].

GASP

GASP treats different concepts in simulation languages than that offered by GPSS or SIMSCRIPT because it is written in FORTRAN and can therefore be recompiled using any FORTRAN compiling system available to a particular analyst. The principal advantages of GASP are its modular characteristics and its machine-independence, which make it easy to alter or expand simulation programs to suit the needs of any given system. Since the entire GASP program is written in FORTRAN, the transfer of a model from one machine to another is limited only by the existence of a FORTRAN translator and sufficient computer memory [104, 181].

GPSS: General Purpose Simulation System

GPSS is a simulation programming language used to build computer models for discrete-event simulations. GPSS has special features for reproducing the dynamic behavior of systems which operate in time and in which changes of state occur at discrete points in time. GPSS offers programming convenience because the GPSS Simulator itself accomplishes many tasks automatically; for example it implicitly collects data describing a model's simulated behavior, then automatically prints out summaries of these data at the end of simulation. GPSS also maintains a simulated clock, schedules events to occur in future simulated time, causes these events to occur in the proper time ordered sequence, and provides a means of assigning relative priorities to be used in resolving time ties. GPSS generally takes longer execution time to perform a simulation than SIMSCRIPT requires [13,77].

LASS (The Logistics Analysis Simulation System)

LASS is a computerized analytical modeling technique for evaluating alternating plans, procedures and policies for a variety of field service and support operations. The LASS system is most suitable for logistics support, distribution and field service in the electronics field; however it has been proven effective in other industries requiring large inventories of replacement parts and service networks that cover vast geographical areas. The key design concept of LASS is to link closed form inventory optimizing models with a service and support-oriented simulation by means of an executive control system to provide a fully realistic set of tools for analyzing the total spectrum of issues impacting field service and support facilities. The flexible structure of the LASS system provides the capability to analyze complex logistic networks under varying assumptions and parameters [24, 47].

MACSYMA (MAC's Symbolic Manipulation System)

MACSYMA is an interactive symbol manipulation language used for performing symbolic as well as numerical mathematical manipulations. It was developed specifically for interactive use, and has capabilities for manipulating algebraic expressions involving numbers, variables and functions. It can differentiate, integrate, take limits, solve systems of equations, factor polynomials, expand functions as laurent or Taylor series, plot curves, manipulate matrices. etc. MACSYMA is applied to the problems of formulating models of aeronautical systems for simulation studies [83].

MACTRAN

MACTRAN is a simulation language designed for the purpose of editing data on an observation by observation basis. It may be viewed as having standard analog function capability such as integration, differentiation, a variety of filters, delay, plus all of the elementary operations and functions. MACTRAN language is related to FORTRAN and has FORTRAN-like statements. It differs from FORTRAN in that a number of FORTRAN capabilities are not needed and hence are not included. On the other hand several operations not available in FORTRAN but handy in editing, have been added to MACTRAN [167].

MARSYAS

MARSYAS (Marshall System for Aerospace Simulation) is a block or equation oriented simulation language that can be used to simulate a system of differential equations or block-oriented systems. MARSYAS has the features of nesting, high flexibility, high adaptability, integration through disc, storage capacity, multiple simulation, and utilizes five numerical integration techniques (Euler, Runga-Kutta fixed interval, Adams-Bashforth predictor-corrector, Sarafyan fifth order variable step and Butcher's fifth order). MARSYAS does not have a debug-aid and this presents a negative aspect [139].

MIMIC

MIMIC is an equation oriented simulation language for continuous systems. It provides a simple method of solving systems of ordinary differential equations. MIMIC utilizes the Runga-Kutta (variable interval) Fourth-order numerical integration technique. It has low flexibility, low adaptability, locks the features of nesting, interactive mode, debug-aid, multiple simulation and storage capability [144, 163].

Monte Carlo Technique

The Monte Carlo Technique is the most general approach used for evaluating the performance of nonlinear systems driven by random inputs. This approximate method is based upon direct simulation and consists of repeated simulation trials plus ensemble averaging. A large number of simulation trials are needed to provide confidence in the accuracy of the results. The expense associated with the Monte Carlo technique limits its utility to that of an evaluation tool [14, 80].

PLANS (Programming Language For Allocation and Network Scheduling)

PLANS is a high level language that allows easy and direct expression of the kinds of functions frequently found in scheduling and resource allocation programs (launches and mission). It has unique capabilities to allow dynamic manipulation of tree data structures at execution time. Another important feature is the close correspondence that exists between basic scheduling functional operations and PLANS statements. This allows both the initial programmer and the maintenance programmer to easily design and modify PLANS programs. PLANS is a generalized, high-level true manipulation language [52].

PLUG

PLUG is a simulation language designed to operate on digital time series on a time-slice by time-slice basis. PLUG operates in two modes, in the first, data is input, processed and output, in the second, no data is input, rather, data is generated internally, manipulated and then output. PLUG manipulations include the following: (1) arithmetic operations, (2) elementary real functions, (3) complex arithmetic, (4) complex functions, (5) digital filtering, (6) data generation and (7) testing and transfer functions. PLUG has a total of forty-six different operations which may be performed, and up to four data functions may be involved in a single operation [167].

SIMPAC

SIMPAC is a fixed time increment simulation language that uses stnadard flow chart symbols. Models formulated in SIMPAC consist of four basic components: activities, transactions, queues and operational resources. Although SIMPAC is characterized by a fairly flexible range of output reports, it is a somewhat more difficult language to learn than GPSS, GASP or DYNAMO [246].

SIMPL/I

SIMPL/I is a process oriented simulation language which is implemented as a superset of PL/I and follows the structure and design philosophy of PL/I. Henceforth, it combines the special purpose features of a simulation system with the flexibility and power of the PL/I high level language. The user has access to the standard mathematical and statistical routines of PL/I libraries, a list processing capability, and specialized facilities necessary for modeling many types of systems [210].

SIMSCRIPT

SIMSCRIPT is a statement-oriented, event-oriented simulation language. SIMSCRIPT is based on FORTRAN it is sufficiently rich and versatile to be used as a general programming language. The static structure of SIMSCRIPT is described by entities, attributes and sets; while the dynamic structure is modeled by events which are changes of state taking place instantaneously at discrete points in simulated time, initiated by the execution of an event routine. Simulation time is controlled by the timing routine which schedules events by means of an events set containing event notices. Each activity in SIMSCRIPT is represented by two events which specify its start and finish [50, 138].

SIMULA

SIMULA is a superset of ALGOL, so, it is really a general purpose programming language despite its name. The instructions have the form of ALGOL statements, and the concept of system classes defines a set of characteristics of special interest in certain application users. SIMULA extends the block concept which is the fundamental mechanism for decomposition in ALGOL, but unlike ALGOL, SIMULA provides input/output statements as a standard part of the language, and to allow flexible string handling, character and text variables are available with different handling procedures [43, 44].

SIMULATE

SIMULATE is a simulation language written in FORTRAN with the objective of determining those parameters that are critical in terms of stability and the decision variables that are of maximum effectiveness in improving stability for large scale models. Program SIMULATE solves any linear systems contained in the model by matrix inversion and nonlinear systems by iterative methods [26, 41].

SLAM

SLAM is an approximate computerized technique which can often be used in the statistical analysis of nonlinear systems. Essentially SLAM is a combination of the CADET and adjoint techniques. In addition to yielding accurate statistical performance projections, SLAM generates an approximate error budget showing how each disturbance influences total system performance. SLAM has been shown to be a useful tool in the preliminary analysis of missile guidance system performance [249, 250].

TAGWAR

TAGWAR is a tactical model for analyzing multiple threat/multiple fire unit engagements. TAGWAR is an event-oriented probabilistic model in which simulated engagement time is stepped as a function of the tactical events being simulated. It has the capability of analyzing engagements in which "M-threats" engage "N-fire units," the latter including both gun and missile systems. Operational factors such as terrain making, fire doctrine and reaction times can be considered [246].

SDL (Simulation Data Language)

SDL provides data structures in which models inputs and outputs can be stored, including time series of observations, statistics and histogram. These structures allow the storage in a single database inputs and outputs for multiple runs of the same model and for runs of different simulation experiments. Besides, SDL provides FORTRAN subroutine calls designed specifically to be used in simulation models for retrieving inputs and for storing outputs. SDL has commands that meet the specialized needs of simulation analysts. For example the commands which perform statistical computations on time series of model outputs let the user select the data by (1) model replication, (2) batches within a single replication and (3) regeneration cycle. SDL provides OIL, a high-level programming language for data manipulation. The OIL processor translates OIL statements into calls to the appropriate SDL subroutines. The operational characteristics of SDL are as follows:

SDL is written in 1966 ANSI FORTRAN IV. It is independent of any simulation language and may be interfaced with any simulation language or other program capable of calling FORTRAN subroutines. It has been implemented on several computers, including an IBM 370/168, a CDC CYBER 175, and a DEC VAX 11/780. Programs written in the SDL OIL language require approximately 300K bytes of memory (overlaid) on the IBM 370/168 system and 210K (octal) words on the CYBER 175 system (without overlays). The portion of the SDL used to interface with simulation programs requires approximately 100K bytes on the IBM 370/168 system and 50K (octal) words on the CYBER 175 system. SDL has been interfaced successfully with the SLAM, Q-GERT, and GASP IV simulation languages. SDL stores the database in a single FORTRAN file accessed by relative record numbers. The accessing of this file varies from machine to machine, but the machine-dependent part of SDL consists of only about 30 lines of FORTRAN. Versions have been coded for most large computers [205, 206, 219].

TABLE 4 APPLICATION OF SIMULATION TECHNIQUES TO AIR DEFENSE WEAPONRY

Application	References
Air defense surveillance systems	59, 207
Air defense gun systems	49
Aerospace/Aviation	92, 153, 172, 204
Aircraft	
General	23, 145
Readiness	101, 162
Automated error tracking	219, 220
Aerial Combat	188, 189
STOL	132
Avionics	55, 235
Helicopter	
General	33, 136
Gun control system	129
Combat	39
Logistics	
Information	88
Human-Weapon interface	11, 119, 120
Supportability	15, 98, 103, 151, 208, 209
Transportation	24, 54
Missile Systems	
Ballistic reentry	40, 65
Digital auto pilot	5
Guidance system	154, 155, 183
Hardware-in-the-Loop	5, 170
Man-in-the-Loop	12
Terminal homing system	171, 243
Target search-kill	30, 34, 35, 51, 85, 86, 137, 149, 179, 185, 198, 213, 221
Radar	10, 91
Tracking	31, 32, 33
Space Vehicles	
Guidance systems	84
Orbital maintenance	76
Hazards	156
Dynamics, trajectory, flight	66, 67, 180
Drop space exploration	125, 135
Obstacle detection/route detection	68, 69, 126, 127, 191, 140, 217, 229
Design, control systems	16, 17, 187, 201, 223, 224, 245
Planning, testing	62, 141, 150
Guidance systems	157
Shuttle	52
Satellites	20, 70

TABLE 5 APPLICATION OF SIMULATION TECHNIQUES TO AIR DEFENSE WEAPONRY (MISSILES)

Application	References
Missiles	
Air defense (General)	7, 18, 42, 90, 94, 106, 107, 109, 111, 112, 113, 114, 115, 116, 130, 142, 169 177, 178, 197, 248, 249, 250
Anti-ballistic	79, 550
Anti-Tank (TOW, Dragon, Viper, Hellfire, Shillelagh, Milan, HOT, Sagger)	536
Anti-radiation (ARM), (HARM)	105, 108, 547
AEGIS	25, 74, 164, 542
Air-to-Air (Phoenix, Sparrow, sidewinder, matra-super)	57, 535, 536
Air-to-ground (Maverick)	546
Anti-ship (Maverick)	546
Copperhead	71, 239
Harpoon in flight	124
NIKE-AJAX	158
NIKE-HERCULES	539
NIKE-ZEUS	159
PERSHING	438, 544
POSEIDON	133
SHRIKE	537
SPRINT	40
Surface-to-air (RAM, DSARC-2, Roland, Chaparral, MLMS, SIAM, Patriot, HAWK, Redeye SA-7, SA-6, SA-2, SA-3)	231, 535, 538, 539, 540, 541, 543, 545, 549
Stinger	16, 5, 38
Winged KSR-11	548

TABLE 6 SPECTRUM OF SIMULATION TECHNIQUES AND LANGUAGES

APPLICABLE TO WEAPONS SYSTEMS ANALYSIS

Techniques and Languages	References
ABSIM	214
ACSL	1
ADSIM	53
APL/FORTRAN	6, 13, 28, 39, 212
ASPOL	464
BDSIM	48
CADET	73, 249
CASE	454
CSMP	29, 81, 95, 96, 97, 163, 218, 223, 224
CSS II	454
DARE-P	46
DYNAMO	184
ECSSL	163, 193, 194, 225
GASP	104, 181, 182, 241
GPSS	13, 77, 78, 92, 191, 199, 203, 235, 247
GSL	75
LASS	24, 47, 427
LPL	2, 3, 4
MACSYMA	83
MACTRAN	167
MARSYAS	139
MILITRAN	8
MIMIC	144, 163
Monte Carlo	14, 80, 100, 118, 197, 219, 251
PLANS	52
PLUG	167
Q-GERT	121
SCERT	454
SDL	205, 206, 219
SIMON	87
SIMPAC	246
SIMPL/I	210
SIMSCRIPT	50, 138, 199, 241, 247
SIMTOS	12
SIMULA	43, 44
SIMULATE	26, 41
SLAM	249, 250
SOL	216
TAGWAR	246
TIGER	130, 226
Hardware-in-the-Loop	5, 170, 457
Man-in-the-Loop	12
Hybrid	84, 132, 187, 194, 229

Chapter 3

WAR STRATEGIES, TECHNIQUES AND TACTICS

Introduction

Strategy is the art of the employment of battles as a means to gain the object of war. In other words, strategy forms the plan of the war, maps out the proposed course of the different campaigns which compose the war, and regulates the battles to be fought in each. Strategy depends for success first and most on a sound calculation and co-ordination of the end and the means. The end must be proportioned to the total means and the means used in gaining each intermediate end which contributes to the ultimate must be proportioned to the value and needs of that intermediate end whether it be to gain an objective or to fulfill a contributory purpose. An excess may be as harmful as a deficiency [460]. Dramatic changes in conventional military capabilities coupled with nuclear parity should greatly increase the importance of conventional military power as well as raise new opportunities and problems for the provision of analytic tools such as game theory by which to appraise their implications and importance.

Game Theory and War Gaming

Game theory considers situations in which a choice has to be made between a number of possible decisions, complicated by the fact that the outcome of the decision does not depend merely on the person who makes it, but also on the decisions of another person whose interests are diametrically opposed to those of the former: what one gains, the other loses. It is assumed that the players make their decisions unknown to each other, and that both know the outcome of any pair of decisions made by them.

Games may be classified under various categories relating to number of moves, number of players and payoff. If each player has a finite number of moves and a finite number of choices available at each move, then the game is finite and has a solution. If player chooses a strategy from an infinite set of strategies, then the game is continuous or infinite. Infinite games do not lend themselves to a general method of solutions. The number of players in a game may be 2-person, 3-person, . . . or n-person. The payoff is zero-sum if players make payments only to each other; otherwise it is non zero-sum. Perfect information games are those that have optimal strategy (saddle point). The players move alternately, and at each move each player is completely informed about previous moves in the game. On the other hand, games with mixed strategy do not have a saddle point; however each player has a probability distribution over the whole set of strategies. Each player selects his strategy at the last moment and thus the opponent is kept uninformed. Other types of games that deal with timing of decisions in a competitive environment are called duels. Each player in a duel wishes to delay his decision as long as possible, but he may be penalized for waiting. Actions in duels are given in advance.

Duels may be classified as follows:

A. Noisy duels

B. Silent duels

C. Silent-noisy duel

1. One bullet each; both have equal worth
2. One bullet each; payoff depends on which duelist survives
3. One bullet; equal accuracies
4. One bullet; arbitrary accuracies
5. One bullet; versus two bullets
6. Many bullets each; equal, arbitrary or monotanic accuracies
7. Continuous fire

A noisy duel is one where the duelist is informed about his opponents actions as soon as they take place. When neither duelist learns when or whether his opponent has fired, then the duel is called silent duel.

The significance of game theory as a decision tool is that it eliminates guessing an opponent's intentions and substitutes an evaluation of the consequences of various possible enemy actions for decision making. A very important and persistent family of applications in game theory involves air defense problems. A general statement is given by Dresher [447].

1. The tactical air war game consists of a series of strikes or moves, each of which consists of simultaneous counter air, air defense and ground support operations by each side undertaken to accomplish a given mission or payoff.

2. Like most battle situations, the combat between air attack and air defense can be viewed as a zero-sum two-person game: The attacker seeks the greatest possible gains in the form of the destruction of targets, and the defender wishes to make these gains as small as possible.

3. An important decision of the defender in a battle situation is the distribution of his total defense resources among his targets. An important decision of the attacker is the distribution of his total attacking force among those targets.

4. On each move, each player (attacker-defender) allocates his tactical fighter aircraft among the usual tasks of (a)counter-air against the enemy's air bases, (b)air defense against the enemy's counter-air operations, and (c)ground support missions against enemy troops on behalf of friendly ground forces.

Other military problems are concerned with the selection and attacking of a target from a number of possible targets, or more generally with the problem of how to distribute one's available resources between a number of possible targets. The enemy will also have resources to deploy in defense of these targets and the effectiveness of our attack will depend partly on chance, partly on the way our forces are distributed between various possible targets, and partly on enemy deployment. Henceforth we have a typical field of application for the theory of two-person zero-sum games [416]. The target selection game may become a BLOTTO game if two additional restrictions hold. The first is that the enemy is restricted to local defense (the defending forces must be allocated to specific targets). And the second is that the payoff for the game as a whole must be representable as the sum of the individual outcomes of the various possible targets.

Table 7 classifies various war gaming applications, strategies techniques and tactics. Table 8 classifies various air defense strategies and gives relevant references. Table 9 gives strategies and tactics that may be considered under various air defense combat situations.

TABLE 7 WAR GAMING STRATEGIES, TECHNIQUES AND TACTICS

War gaming	References
Game Theory	415, 420, 429, 436, 440, 445, 446, 447, 452, 460, 461, 462, 464, 465, 469, 470, 471, 478, 483, 488, 491, 493, 498, 500, 503, 504, 509, 510, 511, 512, 513, 514, 515, 516, 518, 519, 527, 529, 530, 531
War Games	410, 425, 472, 479, 480, 484, 486, 490, 501, 508,
Air defense (general)	403, 404, 411, 418, 419, 422, 428, 432, 442, 443, 453, 487, 489, 532,
Antiballistic missile	439
Antisubmarine	434
Attrition	426,467
Blotto	423, 424
Bomber Interceptor	431
Combat (duels)	406, 407, 408, 409, 421, 506, 528,
Fighter vs. Bomber	416, 433
Hunter vs. Bomber	463
Lanchester	448, 520, 521, 522, 523, 524, 525,
Missile vs. Bomber	417
Missile Penetration	468
Point and Target area	451, 476, 526, 534,
Pursuit and Evasion	430, 450, 458, 459, 466, 507
Search-Attack-Defense	435, 485, 497, 505
Submarine vs. Submarine	413, 444, 475, 499
Logistics	405, 412, 414, 437, 441, 445, 455, 477, 481, 495, 533

TABLE 8 AIR DEFENSE STRATEGIES, TECHNIQUES AND TACTICS

Strategy Problems	Techniques	Tactics	Reference
Fighter vs. Bomber air-to-air combat duel	Two-person-zero-sum-game	Pure strategy for Bomber and a mixture of two firing times for the fighter	527
Missile attack on point target heavily defended by anti-missiles	Two-sided optimization game	String of attack objects: warheads and decoys arriving at time intervals.	468
Tactical air warfare Air defense ground support Air defense counter air	Two person multi-wave game (Mini-max criteria)	The stronger side splits his forces, the weaker side uses mixed strategy	489
Air defense of an air-field against enemy air attack (Fighter vs. SAM performance and cost effectiveness)	Two-person zero sum game. One play game.	Optimal cost/kill Optimal # of weapons delivered by enemy for specified defense and offense costs	422
Projectiles (Attacker vs. Target)	Mixed strategy game	Target takes a complicated sinuous motion with a speficied spectrum	459

TABLE 8 (Cont'd)

Strategy Problems	Techniques	Tactics	Reference
Attack (Searcher vs. target) (Helicopter vs. submarine)	Discrete sequentially compounded search game	Target shows tendency to remain near datum while searcher should prefer the outside region in the early stages of game.	485
Attack (searcher vs. target) (Submarine vs. submarine with restrictions)	Pure strategy search game	Search intermittantly	444
Attack (searcher vs. target) (submarine vs. submarine)	Two-person zero-sum game	Pure strategy searcher maximizing target minimizing	413
Hunter - Bomber	Two-person zero-sum game	Maximin strategy	463
Strategic deterrence (defense of Missile Silos)	Game theory	Maximin strategy	440
Fighter vs. Bomber Missile vs. Bomber Submarine vs. Destroyer Tank vs. Infantry	Blotto Games	Transportation problem techniques	417

TABLE 8 (Cont'd)

Strategy Problems	Techniques	Tactics	Reference
Search, avoid, attack (Barrier vs. Transitor submarine)	Two person game	Defender takes any location for which range fills the unit interval. Transitor moves at distance greater than half the range of Barrier.	499

TABLE 9 AIR DEFENSE STRATEGIES

Situation	Strategy
1. One against one	
The situation is characterized by:	The strong one should:
1. High level of detail	1. Attack first (use offensive policy)
2. Accuracy, reliability, cost	2. Attack head-on (move directly on enemy)
3. Crew initiative, training, response	3. Utilize elements of speed, sudden change of front, movement and surprise.
4. Crew efficiency under shock and fatigue	
5. Electronic counter measures	
6. Evasive maneuvers	
7. Speed, altitude, weather, terrain	
8. Number of rounds of ammunition	
9. Maximum rate of permissable fire	
10. Usable operational life of weapon system	
2. One against few (few against many)	
This situation is characterized by:	The weak should:
1. knowledge of number of combatants	1. Seek and exploit line of least expectation
2. Enemy configuration, planning density, cover, etc.	2. Seek and exploit line of least resistence
3. Crew capability, quality, initiative, etc.	3. Use strategy of indirect approach
4. Adequate command system	4. Lure enemy into unprofitable position
5. Command plan (flexible, rigid)	5. Use strategy of limited aim
6. Effect of Communication failure	6. Use strategy of flexible command
7. lethal area	7. Attack before strong enemy splits his forces

TABLE 9 AIR DEFENSE STRATEGIES (Cont'd)

Situation	Strategy
3. Many against many This situation is characterized by: 1. Prior knowledge of qualitative and quantitative superiority 2. Maintaining of objective yet with self modification if necessary 3. Command is accessible on the spot 4. As in 1 and 2.	The strong should: 1. Always try to have initial advantage over enemy 2. Use offensive policy with initial, sudden and severe attack (mystify, mislead and surprise) 3. Attack enemy's rear 4. Use distributed strategic advance 5. Use methods of attrition rather than maneuver. 6. As in 2.

Chapter 4

SUMMARY AND RECOMMENDATIONS

Weapons systems must be planned and anlayzed with an integrated approach that addresses the needs of the whole tactical arena rather than a case-by-case approach. This report puts forward a methodology for the analysis of weapon systems. Chapter 1 examines and evaluates various criteria and attributes that relate to system effectiveness such as system performance, operational readiness, life cycle costing, logistics, reliability, availability, maintainability, design adequacy, design to cost (affordability), producibility, operability, capability, etc. The optimization of system effectiveness is obtained by balancing of the various conflicting criteria cited above. These criteria and their attributes are so interrelated that they must be viewed together within the framework of the overall system to which they contribute. Chapter 2 identifies, defines, evaluates and classifies a spectrum of simulation techniques and languages that are applicable to weapons systems analysis and air defense weaponry. The simulation language best suited for a particular simulation study depends upon the characteristics of the system and upon the programming skill of the individual conducting the study. As a general rule an increase in the flexibility of a simulation program is obtained at the cost of requiring more understanding of programming techniques. Similarly reductions in programming time achieved through the use of simulation languages are associated with increases in computer running times and computer costs. The decision whether to use a particular simulation language may be influenced by the availability of computer hardware, availability of programmers knowledge in particular computer languages, cost of programming and cost of computer time. Simulation languages that are designed for modeling and evaluating the performance of continuous systems are considered adequate to describe and analyze weapons systems. Chapter 3 addresses and evaluates various air defense war strategies, techniques, and tactics.

This report emphasizes the following recommendations:

1. Simulation modeling rather than analytic solutions seems to be more realistic and strongly suggested for evaluation of system effectiveness of weapons systems and air defense weaponry.
2. Although the ability to function according to design criteria is one of the bases by which weapon systems should be evaluated, it is recommended that future weapons systems be considered for dual-capability.
3. The inclusion of a discriminate weapon capability.
4. Other criteria for design and analysis of weapon systems should be considered, these are classified as follows:
   a. War strategy (weapons systems objectives)
      1. Deterrence by dominance
      2. Deterrence by punishment
      3. Deterrence by denial
      4. Deterrence by flexible response
      5. Deterrence without self destruction
      6. Deterrence by selective targeting
   b. Weapons systems usage (allies)
      1. Pursuit of standardization
      2. Collaborative acquisition, interoperability and defense cooperation
   c. Future modes of warfare and strategy
      1. Dual capability.
      2. Enhanced discriminate weapon capability.
      3. Ground stationed and space stationed direct energy weapons (infrared and ultraviolet lasers, particle beams).
      4. Maneuver dominated offensive weaponry
      5. Missiles made hard to be detected
      6. Ease of dispersal and concealment
      7. Increased capability to project power from a distance
      8. Increased capability by using precision guided munitions
      9. Lower force-to-space ratio
      10. Use of low altitude defense systems.

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